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Gravity separation at variable 'g' for management of mineral wastes and pollution

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ABSTRACT

The treatment of mineral wastes in the form of slimes and its utilisation, for management of pollution and conservation of mineral wealth, have become very important now-a-days. Multi Gravity Separator (MGS) is the latest inclusion to various gravity separation machines developed for the treatment of fines and ultrafines. In this paper, results of recent studies carried out at NML with MGS using slimes of chromite ore, iron ore, phosphatic soil etc. are discussed to evaluate the effectiveness of the equipment for the treatment of slimes. In most of the cases, three to four fold upgradations have been achieved even at very fine sizes.

INTRODUCTION

Slimes, produced during processing of ores/minerals and rejected as wastes, create environmental problems. Recovery of values from these slimes is gaining increasing importance of late. Wastes generated by the mining, mineral processing and metallurgical industries, totalling about 2 billion ton per annum, are to be disposed of with a minimum environmental degradation and at acceptable cost. Some of the metallic and mineral constituents of these wastes are valuable, and their recovery can lead to substantial conservation of mineral and metal resources. Researchers are identifying ways and means to recover the valuable constituents from the wastes. The ultimate aim is, of course, to develop technology where every input into the plant delivers products of commercial value leaving nothing to discard (zero waste technology)[1].

To upgrade slime is a difficult problem in Mineral Processing and particularly in gravity separation where ultrafines pose special problem. For very fine particles (less than 75 microns), the force associated with the water flow becomes dominant over that associated with gravity. As a result, a large part of the valuable minerals contained in these fine particles prove to be irrecoverable with traditional methods of gravity separation. To overcome this problem, various gravity separation methods and machines have been developed over the last few decades viz. Fines table, Multi-deck separator, Cross belt concentrator etc. The new devices and processes, as compared to flotation of slimes, have the advantages of adaptability, low cost and less environmental pollution[2,3]. Very recently, Multi-gravity separator (MGS) has appeared in the market and seems to be very promising in tackling the problem of fines and ultrafines. This equipment can be operated at variable 'g' depending on the characteristics of the slurry to be treated. The potential and limitations of MGS, however, are yet to be fully understood[4-6].

Since installation of the MGS at the National Metallurgical Laboratory in 1992, several studies have been carried out on samples of Indian and foreign origins viz. lean tungsten ore, iron ore, chromite ore, phosphatic soil etc. varying different design and operating variables. Some of the results of those studies are presented in this paper. MGS studies on chromite ore slime at 100% -60 micron size resulted in about fourfold upgradation of Cr_2O_3 content in the concentrate. For the slime of phosphatic soil at 80% - 8 microns size, a concentrate of comparable upgradation in quality could be obtained. Similarly, for an iron ore slime at - 147 microns size, a concentrate assaying 65.58% Fe, 2.0% Al_2O_3 and 1.52% SiO_2 could be produced from a feed assaying 55.51% Fe, 7.49% Al_2O_3 and 4.24% SiO_2.

Multi-Gravity Separator

The MGS is used to separate two minerals from each other or to separate a group of heavy minerals from lighter minerals provided there is a reasonable difference in specific gravities. It consists of a slightly tapered open ended drum that rotates in a clockwise direction and is shaken sinusoidally in an axial direction. There is a scraper assembly, inside the drum, which rotates in the same direction but at a slightly faster speed. Feed slurry is fed midway onto the internal surface of the drum via an accelerator ring launder. Wash water is added via a similar launder positioned near the open end of the drum. Due to high centrifugal forces, the dense particles from a semi solid layer against the wall of the drum and are conveyed towards the open end of the drum by the scrapers when it discharges into the concentrate launder. The less dense minerals are carried by the flow of wash water towards the rear of the drum to discharge into the tailing launder.

The design and operating parameters which affect separation are rotational speed, frequency and amplitude of the shake, slope of drum with the horizontal, wash water flow rate, feed rate and feed pulp density. The specially significant parameter of variable 'g' is obtained in the MGS by changing the RPM of the drum and is empirically given by the following equation :

$$g = 5.6 \times 10^{-4} \times D N^2$$

where D is the diameter of the drum (in m.) and N is the rotational speed of the drum (in RPM). Therefore, drum speeds of 160 to 240 RPM, with a diameter of 0.5 m produce 'g' values of 7 to 16.

Experiments and observations

To evaluate the effectiveness of the Multi-gravity separator, experiments were performed using slimes generated after processing of low grade chromite ores, washing of iron ore and beneficiation of phosphatic soil. In each case, effects of variation of different design and operating parameters were studied to obtain optimum combination.

Chromite ore slime

During beneficiation of low grade chromite ores a large amount of slime is generated which still contains certain amount of mineral values. Recovery of any portion of this mineral value, otherwise rejected as wastes, is of great significance in terms of overall economy of the process and conservation besides waste management.

The chromite slime sample analysed 10.52% Cr_2O_3, 29.68% Fe (T), 33.6% SiO_2 and 13.13% Al_2O_3. It was treated on MGS varying the design and operating parameters. The sample was 85% - 20 microns in size, as presented in Table-1. Results of MGS studies are plotted in figures 1-4. All the figures represent grades of Cr_2O_3 and Fe (T) in the concentrates. While figures 1 and 2 show the effect of variation of design variables viz, rotational speed and tilt angle (slope) in separating the mineral values from the gangue minerals, figures 3 and 4 represent the effect of variation of wash water flow rate and feed pulp density. From figures 1 and 2, it is observed that with increasing rotational speed Cr_2O_3 content decreases but increase in tilt angle initially improved the grade substantially though further increase only resulted in marginal improvement. On the other hand, increase in wash water flow

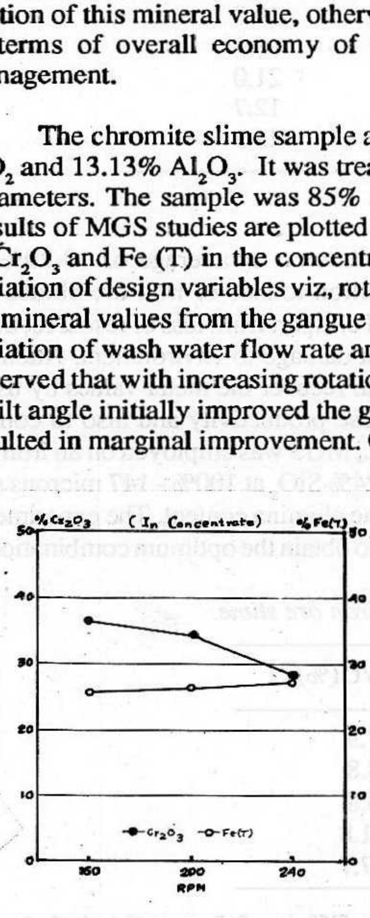

Fig.1 : Effect of variation of rotational speed on chromite ore slime

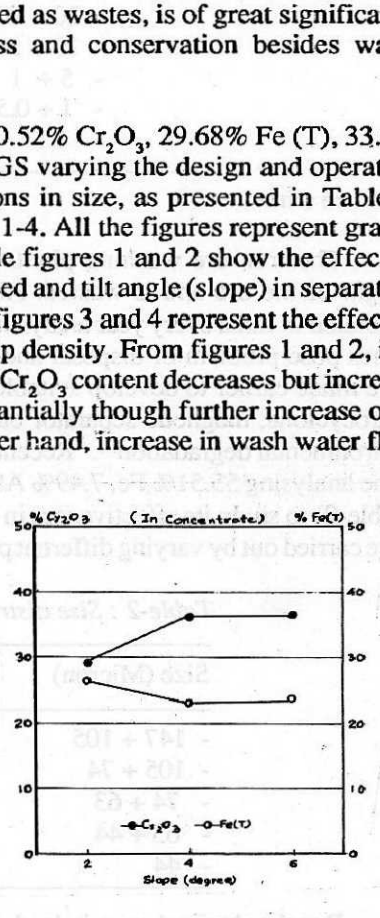

Fig.2: Effect of variation of slope on chromite ore slime

rate was found to improve grade linearly (Fig.3) and similar trend prevailed in the case of increase in feed pulp density. In all the above cases three to fourfold increase in Cr_2O_3 content was observed but change in Fe content with respect to feed was marginal.

Table-1 : Size distribution of chromite ore slime

Size (Micron)	Wt. (%)
- 60 + 50	1.5
- 50 + 40	2.0
- 40 + 30	3.8
- 30 + 20	7.6
- 20 + 10	19.0
- 10 + 5	8.9
- 5 + 1	21.0
- 1 + 0.5	12.7
- 0.5	23.5

Iron ore slime

The iron ore washing plants generate slime on an average of 10-20% by weight of the ore and is wasted. About 12 million tonnes of iron ore slimes are generated in India every year analysing 50-60% Fe. Apart from loss of resource, these slimes pose problem of disposal and consequent damage to environment. Attempts were made earlier to develop suitable methods to recover the metal values by using hydrocyclone, magnetic separator etc., to increase productivity and also to control environmental degradation[7]. Recently, at NML, MGS was employed on an iron ore slime analysing 55.51% Fe, 7.49% Al_2O_3 and 4.24% SiO_2 at 100% - 147 microns size (Table-2) to study its effectiveness in reducing the alumina content. The experiments were carried out by varying different parameters to obtain the optimum combination[5].

Table-2 : Size distribution of iron ore slime

Size (Micron)	Wt. (%)
- 147 + 105	7.9
- 105 + 74	8.8
- 74 + 63	3.8
- 63 + 44	11.8
- 44	67.7

Results obtained were, indeed, encouraging. Effects of change of shake intensity i.e., shake frequency and amplitude are plotted in Figs 5 and 6. While Fig. 5 shows that increase in frequency diminishes Al_2O_3 content, at maximum amplitude there occurs a sharp fall in the value of alumina content in the concentrate (Fig.6).

Phosphatic soil slime

A phosphatic soil slime, assaying 7.33% P_2O_5, 16.68% Fe, 22.4% SiO_2 and 21.4% Al_2O_3 at 95% - 30 microns (as presented in Table-3), was generated during desliming of a phosphatic soil sample (10.28% P_2O_5). MGS studies on this slime showed that a concentrate assaying 25% P_2O_5 could be produced.

Table-3 : Size distribution of phosphatic soil slime.

Size (Micron)	Wt. %
- 80 + 60	0.8
- 60 + 50	0.9
- 50 + 40	1.2
- 40 + 30	2.0
- 30 + 20	4.1
- 20 + 10	10.5
- 10 + 5	4.6
- 5 + 1	29.8
- 1	46.1

DISCUSSION

From the above study it is clear that different design and operating parameters affect the performance of MGS in different manner (Figs. 1-6). For any particular application, depending on the nature of the material to be treated and the specifications of the concentrate to be produced, optimum combination of parameters is to be chosen. In general, when the rotational speed of the drum increases, all other variables remaining constant, the 'g' value acting on the mineral particles increases; the effect of shake is to impart the additional shearing action on the particles which aids the separation process. Increasing slope angle increases the throughput a little but larger slope angle tends to reduce heavy mineral recovery. Wash water cleans the concentrate by carrying away lower density minerals released by the ploughing action of the scrapers. Feed pulp density can varied within the range of 10 to 50% solids w/w. However, higher feed densities should be counter balanced by the addition of more wash water.

From Fig.1 it is observed that nearly fourfold upgradation of Cr_2O_3 value could be achieved at 160 RPM but an higher RPM's the Cr_2O_3 content of the concentrate decreased sharply with a little increase in the Fe-value. Apparently, under

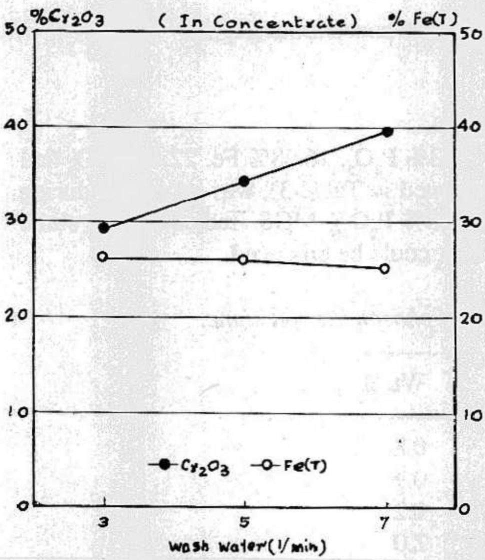

Fig.3 : Effect of variation of wash water on chromite ore slime

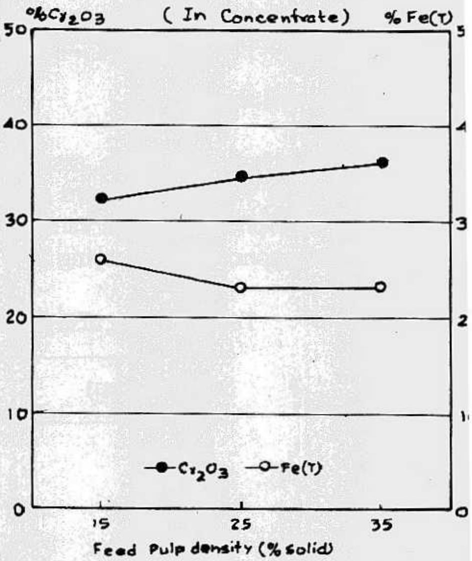

Fig.4 : Effect of variation of feed pulp density on chromite ore slime

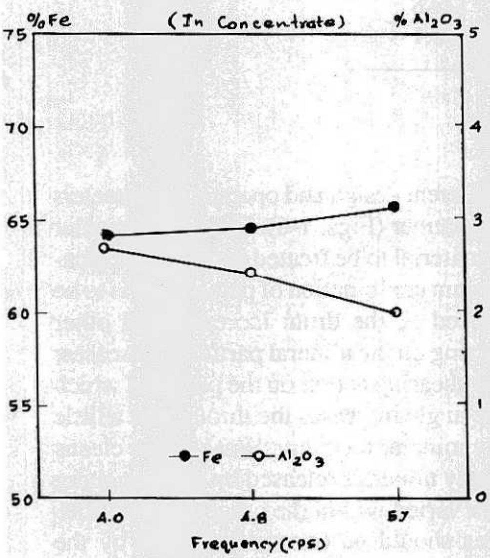

Fig. 5 : Effect of variation of shake speed on iron ore slime

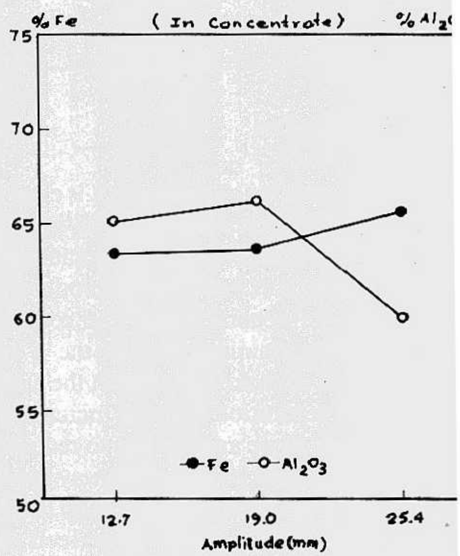

Fig.6 : Effect of variation of shake amplitude on iron ore

conditions of higher 'g' minerals heavier than chromite (e.g. magnetite, hematite etc.) are being transported to the drum wall in preference to chromite. The same trend would, of course, be observed in the case of locked particles also - containing chromite and heavier iron bearing minerals. Fig.3 clearly depicts the cleansing effect of wash water on the concentrate; while the very heavy Fe-minerals steadily adhere to the drum, the relatively lighter chromite gets more and more clean as increasing wash water remove more and more lighter gangues. Similarly, the beneficial effect of the shake intensity to eliminate lighter gangues is apparent from Figs.5 and 6. It is observed that as the shake intensity increases, i.e., as the separating layer gets more agitated more gangue minerals get released and eliminated. It is significant to note that by employing MGS the detrimental alumina content of the slime is brought down from 7.49 to 2.0%. Besides revealing significant characteristics of the slimes as discussed above, the studies also indicate that it is possible to salvage useful components from these slimes which would have been otherwise wasted and added to pollution problems.

However, a few constraints on the use of MGS must be mentioned, especially when dealing with slimes. A clear understanding of the mineralogy and mineragraphy of the slime is required to select parameter setting of the equipment. Conventional optical microscopy is ineffective in most cases to provide above mentioned information for the slimes because of their very fine sizes (please see from Table-1 to 3). Electron microscopic techniques (EMPA and SEM) are helpful in this regard but are expensive and not available easily. Further, the equipment is yet to be developed for true large scale continuous operation. Notwithstanding these constraints, the MGS can be gainfully employed to recover high value concentrates like precious metals, minerals etc. from wasted slimes. This, of course, is in addition to more conventional use of the equipment for the treatment of ores, heavy mineral sands etc.

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